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KANSAS CITY POLLUTION SURVEY USING IR DETECTION TECHNIQUE

E. C. Cannard, et al

HRB-Singer, Incorporated
State College, Pennsylvania

23 October 1961

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FINAL REPORT ON KANSAS CITY POLLUTION SURVEY USING IR DETECTION TECHNIQUES

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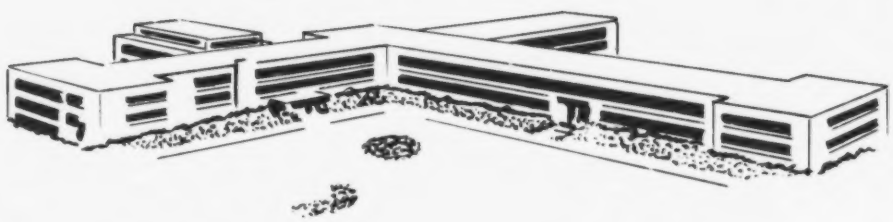

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PRELIMINARY REPORT ON KANSAS CITY POLLUTION SURVEY USING IR DETECTION TECHNIQUES

Prepared for
Department of Health Education and Welfare
Public Health Service

Only the first three copies are classified Confidential

23 October 1961

Copy No. // of 113 Copies

Prepared by: E. C. Cannard
J. G. Hogan

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I. INTRODUCTION

A. GENERAL

The problem of stream pollution is assuming more and more importance in our efforts not only to maintain but also to increase the available supply of potable water for both industrial and domestic uses. Though important in all areas, this problem becomes of critical interest in watersheds which serve highly concentrated urban populations and industrial areas. Efforts to locate, identify, and eliminate as many sources of contamination as possible are continually being made by many state and national groups.

One such large scale investigation has been made by the Public Health Service in the vicinity of Kansas City. All possible sources of pollution of the Missouri, Kansas, and Blue Rivers were located and identified. Results of this pollution survey have been published in the Transcript of Hearing, Pollution of Interstate Waters, Missouri River and Connecting or Tributary Waters in or Adjacent to the Kansas City Metropolitan Area, Department of Health, Education, and Welfare, June 13-17, 1960.

B. THE PROBLEM

The present investigation has been a preliminary effort to determine the feasibility of using IR equipment to detect and thereby accurately to locate sources of stream pollution. Although IR equipment has not previously been used in this specific application, the possibility of such use had been established by results obtained in many of the experimental IR missions flown by HRB-Singer, Inc. These experimental results have demonstrated that extremely small temperature differentials across a body of water can be detected by IR equipment utilizing detectors of sufficient sensitivity. Sewer outfalls, power plant effluents, small stream inlets, oil slicks, bottom discontinuities, wave irregularities, and other surface phenomena have all been detected with fair regularity. Because this is true, and because nearly all outfalls which might contribute to the pollution of a stream probably have a temperature a few degrees above or below the temperature of the main stream body, it follows that such sources of pollution can be detected using IR techniques.

The intent of the present preliminary program is to determine what degree of success can be achieved in such aerial pollution surveys and to collect sufficient data to determine whether further investigation of this problem using IR detecting equipment is warranted.

C. SUMMARY OF RESULTS

Section IV of this report presents a detailed discussion of the results obtained during the survey, beginning with the definition of sources as to possible or definite and the factors involved in the determination of these classifications. Also considered are the parameters involved in executing the data-collecting flights. The total sources detected during each flight are then given as a prelude to the distribution maps. These maps are a ground representation of the results of the study in that they demonstrate pictorially the location, classification and identification of the sources detected. Also included in this section is a list of the sources detected and probable causes for those not detected. The Section is concluded with a discussion of comparative prints of the film results under various conditions. Because of the data given and the CONFIDENTIAL security classification of these prints, they are not included in the unclassified version of this report.

The following facts are noted in summary of the Section: A total of 60 sources were detected, 57 of which were identified as actual sources; the other 3 were comprised of a creek input to the river and two blanks (no source at the point). During the June 5th flight, 28 definite sources were detected and 24 were seen as a result of the June 6th morning flight. The daylight flights yielded an additional 26 possible sources of which 23 proved to be actual sources. This was verified as a result of a ground survey conducted in the Kansas City area with the aid of Public Health Service personnel of the Regional Office in that city. With their cooperation, it was also possible to identify each of the 57 known sources.

II. PRINCIPLES OF INFRARED

The infrared portion of the electromagnetic spectrum lies between visible light and the microwave region of high definition radar. Any object at a temperature above absolute zero radiates energy in all wavelengths. Such radiation is the result of molecular thermal agitation, and maximum radiation will occur near a specific wavelength which is a function of the temperature of the object. This maximum occurs at shorter and shorter wavelengths as the temperature is increased. The amount and wavelength distribution of the energy emitted by any body above absolute zero is distributed according to theoretical laws that have been experimentally verified. The thermal radiation of most terrestrial objects is located in the infrared portion of the spectrum. This radiation possesses the same characteristics as other portions of the electromagnetic spectrum and is propagated through space in the same manner. The fact that infrared is most readily converted into thermal energy when it strikes an object distinguishes it from other types of radiation. However, it should not be confused with heat waves, the transfer of thermal energy by conduction or convection, which require a physical medium such as air; infrared energy propagates through a vacuum as well.

Remote measurement of infrared has become possible in the last 20 years by the development of fast, sensitive infrared detectors. Present day instrumentation consists of an optical system which collects radiation from a narrow field of view and converts the received energy to an electrical signal. This electrical signal can be amplified and measured directly, used as a primary input to a servo system for control purposes, or used to modulate the intensity of an electron beam or light beam for infrared photography.

III. THE EXPERIMENT

A. EQUIPMENT USED

The equipment utilized in these exercises consisted of the following:

1. AN/AAD-2( ) Infrared Detecting Set
2. P type Gold-doped Germanium Detector
3. Indium Antimonide Detector
4. Optical Filter, 3 micron cutoff
5. Oscilloscope, Monitoring
6. HRB-Singer, Inc. Cessna 310-B Aircraft.

AN/AAD-2( ) is a miniaturized line scanning aerial mapping device. In operation, the equipment is installed in the aircraft, the appropriate infrared detector is installed in the system and cooled to liquid nitrogen temperature, and a loaded film magazine installed. As the plane traces out the chosen flight path, the device produces a line-by-line scan of the terrain beneath the aircraft. The scanning method itself is termed object scanning. This means that the scanning mirror is placed between the focusing element (paraboia) and the object being scanned instead of between the focusing element and the detector as in image scanning. The rotation of the scanning mirror, in conjunction with its companion optics, produces a scanning motion perpendicular to the aircraft line of flight.

As the scanner rotates, light (or infrared) rays are received from various points on the ground. The electrical output of the detector varies with the amount of energy received from each point in the scan. This output is amplified and used to intensity modulate a glow tube which, after being focused by a printing optical system, exposes the record film in relationship to the detector output. Gray scale on the exposed film is determined by the relative strength of the received rays and resultant detector output. Very hot bodies overexpose the film and produce white areas on the positive print; very cold bodies underexpose the film and produce black areas on the positive print. Gray scales are produced by bodies radiating at various temperatures between these two extremes.

An oscilloscope is mounted in the aircraft in order to provide continual monitoring of the relative strength of signals. An optical filter is used in conjunction with the detectors. Reasons for this and the effects caused are included in the discussion of Results (Section IV).

B. DATA COLLECTION

Using, as a guide, the map of Metropolitan Kansas City Area Sewer Outfalls which appears in the hearing transcripts, flight paths were planned along the Missouri, Kansas, and Blue Rivers. The paths over the respective rivers covered the areas containing the greatest number of known sources of pollution.

A primary effort in any particular application of IR technique requires that flights be planned to provide the greatest amount of information. Therefore, it was necessary to include many variations of operating conditions in order to learn which method(s) would produce the desired result. Such conditions included determination of optimum altitude, air speed, and numerous technical variations in the operation of the IR device.

Data collection flights were made at the following dates and times:

6-4-61	-	0100 hrs. to 0330 hrs.
6-4-61	-	1200 hrs. to 1445 hrs.
6-5-61	-	0100 hrs. to 1505 hrs.
	-	1312 hrs. to 1505 hrs.
6-6-61	-	0050 hrs. to 0230 hrs.

IV. RESULTS

A. GENERAL

Of the five data-collection flights performed, four resulted in quality imagery. The flight conducted on 6-4-61 at 0100 hours produced a comparative amount of exposed film. However, results from the entire flight were destroyed because of a malfunction in the developing tank. The four remaining flights, two during daylight hours and two under nighttime conditions, each produced imagery valuable in the compilation of results.

The sources detected as a result of the study are separated into two distinct categories, (1) definite and (2) possible. Interpretation of the film exposed during nighttime yielded sources considered definite. Gray scale difference between pollution sources and the river into which they are dissipated was the factor involved in determining whether a source should be considered definite or possible. Under nighttime operating conditions, the exposed film is a true infrared recording. This means that variations in gray scale are a direct result of the temperature and degree of emissivity of the object(s) being scanned. Since the emissivity of any object is constant, it follows that the major factor contributing to gray scale differences is temperature. From this, we may consider a source as definite whose gray scale differs from that of the river into which it is dissipated. In the great majority of cases, the temperature of the source was relatively greater than that of the river and produced either a white area on the positive print or an area whose gray scale is lighter than that of the river. (An exception to the rule is AG10A and may be seen in Figure 8 on page 22.)

The foregoing discussion of the effect of temperature differential does not hold during daylight hours. Under daylight conditions, film exposure is a direct result of the reflectivity of the object(s) being scanned. Reflection in most cases is so strong that it completely obliterates any existing temperature differential. This means that the gray scale of even a known source of pollution may be identical to that of the river and the resultant film record is like that of a conventional photograph. The data gathered under these conditions cannot, therefore, be used to determine definite sources. However, useful information may still be acquired by virtue of the fact that any obvious outfall or irregularity in the natural bank of the river can be seen. Even if the gray scale of one of these was observed to be the same as that of the river, it was defined as a possible

source and recorded as such. The effect of the strong signals due to reflection can be somewhat alleviated by use of an optical filter placed between the detector and collecting optics. Depending upon the spectral characteristics of the filter, a definite portion of the electromagnetic spectrum may be eliminated. During one phase of the data-collection flights, a 3 micron filter was used. This means that most of the visible energy reflected was filtered out. The fact that only one definite source was detected as a result of this procedure may be attributed to the additive effect of several causes such as: (1) a 3 micron filter eliminates a portion of the infrared spectrum as well as visible, (2) the effect of reflectivity is greatly reduced but still is the major factor in the degree of film exposure, (3) only one source produced a sufficient temperature differential to override the reflection effect.

B. PARAMETERS

The parameters involved in the execution of the data-producing flights were:

1. Aircraft velocity
2. Aircraft altitude
3. Infrared detector with and without filter
4. Time of flight
5. Location

In all examples of comparative prints shown in Section IVG, aircraft velocity and altitude were held constant. Nominal rates for these 2 parameters were determined during the flights. It was learned that a speed greater than 130 knots was not only unnecessary but also made it difficult to negotiate bends in the rivers without exceeding the 30° stabilization limitation of the recording device.

An altitude of 1000 feet was necessary in order to include all of the Missouri River's width and still map enough terrain to enable location of sources. A lower altitude was desirable over the Blue River because of its relatively small width. However, the twisting nature of the stream made it impossible to negotiate at a lower altitude. The decrease in instantaneous field of view with increasing altitude places an upper limit on the altitude to be used. Therefore, only one

pass over each river area was made at 2000 ft. during a daylight flight. Subsequent study of the results verified the decision, since a total of 37 possible sources were seen as compared with the 60 seen at 1000 feet. Also of note was the fact that at 2000 ft. altitude, no sources were seen in the Blue River area.

Time of flight, detector with and without filter, and location were variables used in selecting prints for a comparative study of the results. Combinations of these variables are discussed in reference to appropriate prints which were selected as representative of the results obtained.

C. TOTAL SOURCES DETECTED

As described in the previous discussion, results obtained during the flights conducted under nighttime conditions yielded those sources considered definite. Daylight operation resulted in films used to determine additional possible sources. An over-all total of 60 sources were detected, of which 26 were originally classified as possible and 34 considered definite. A total of 28 definite sources were detected as a result of the June 5th morning flight. Definite sources detected June 6th (nighttime) numbered 24. These totals are graphically represented in Figure I on page 9 .

After a preliminary study of these results, a ground observation of the area under study was made in conjunction with the Kansas City Office of the Public Health Service. With the aid of Messrs. Donald A. Townley and Richard G. Hunsinger, a visual check of a representative number of sources was made, concentrating for the most part on those outlets not detected in an attempt to determine the reasons for not detecting those sources. It was also possible, with their cooperation, to identify each of the 60 sources detected, 57 of which proved to be actual outfalls.

D. DISTRIBUTION MAPS

1. Metropolitan Kansas City Sewer Outfalls

Figure 2 on page 10 is a reproduction of the map printed in the transcript of "Hearing on Pollution of Interstate Waters, Missouri River and Connecting or Tributary Waters in or Adjacent to the Kansas Cities Metropolitan Area." This map was prepared by the Regional Office of the Department of

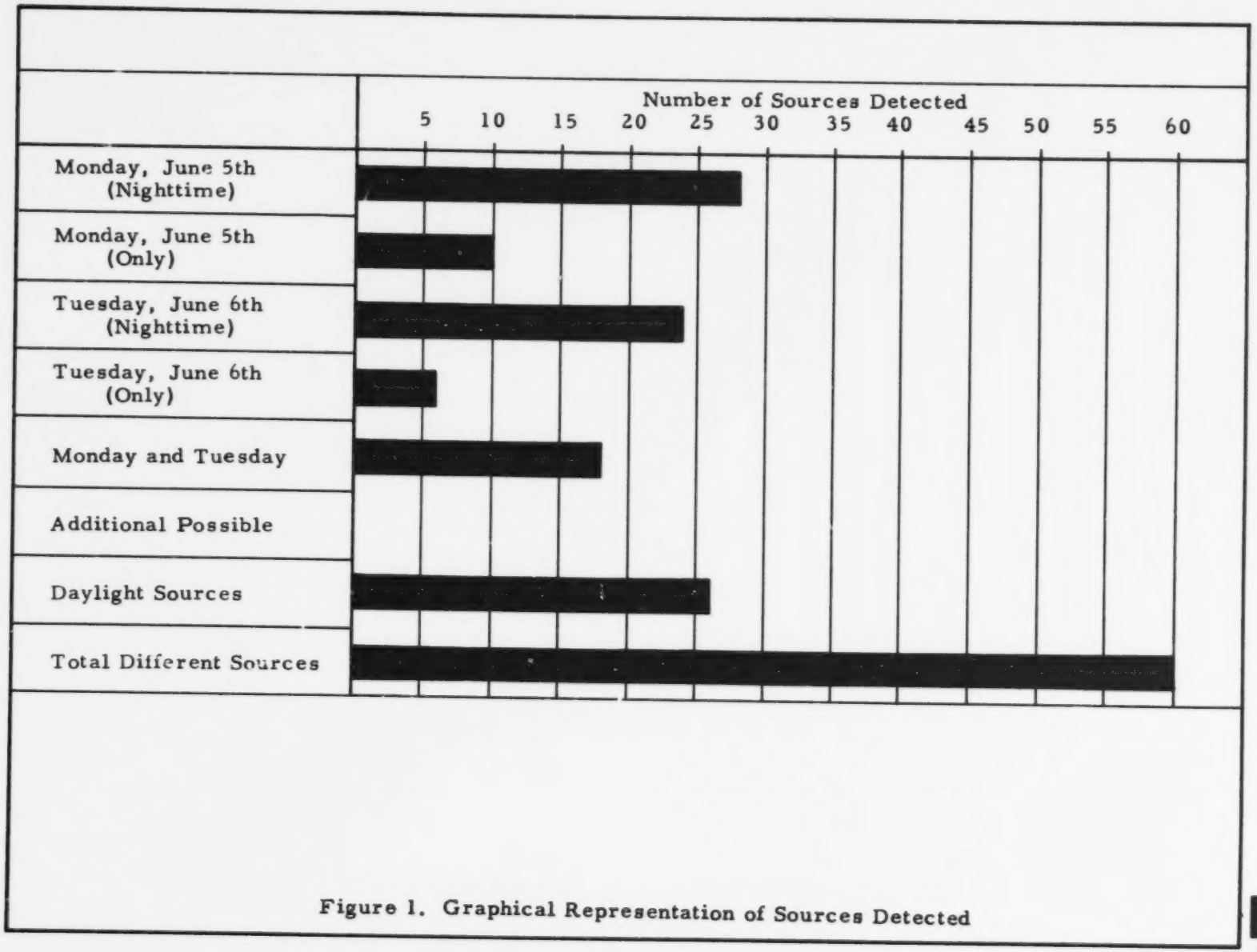

Figure 1. Graphical Representation of Sources Detected

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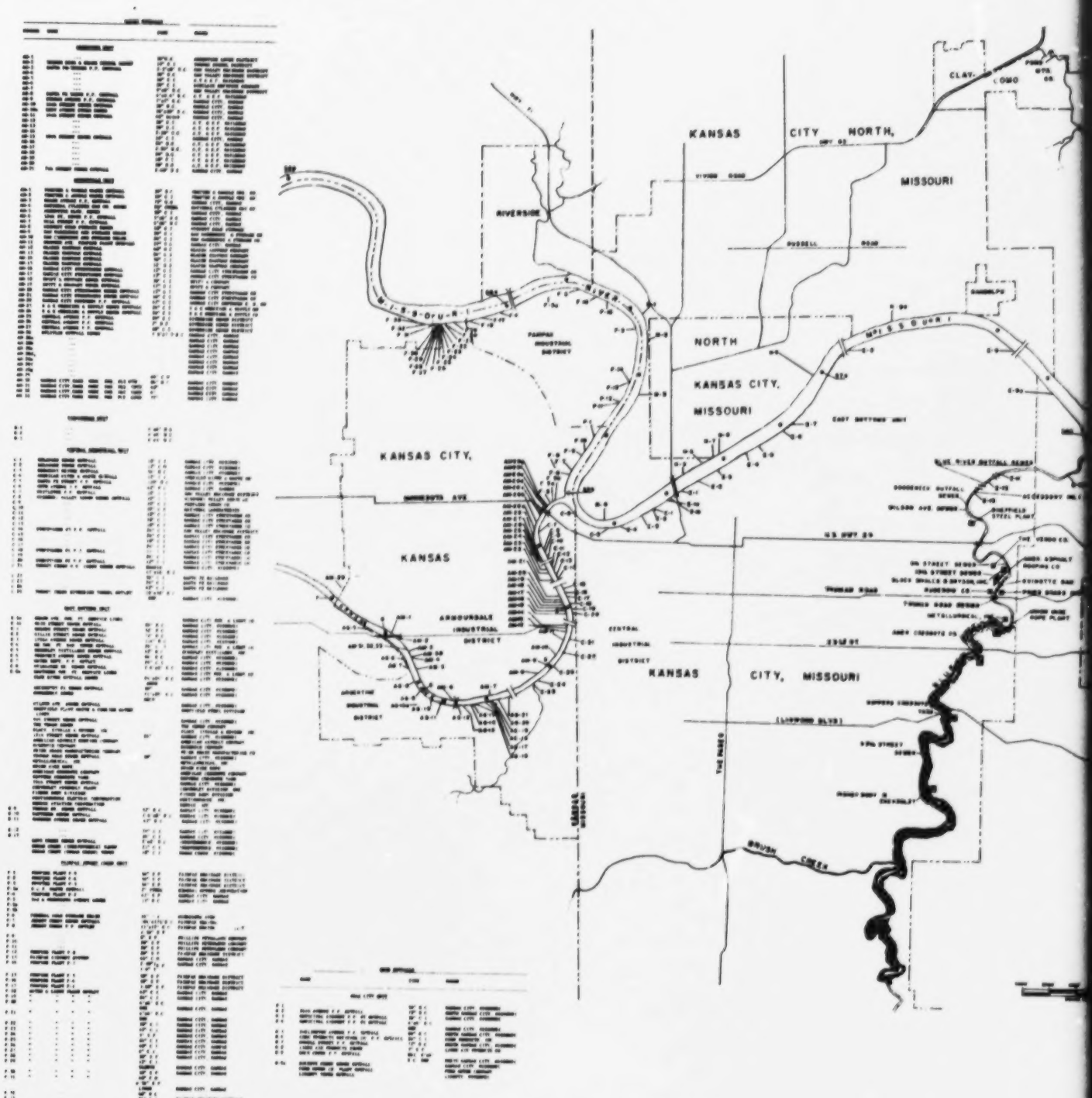


Figure 2 - Metropolitan Kansas City Area Sewer Outfalls

Figure 2 - Metropolitan Kansas City Area Sewer Outfalls

Heal h, Education, and Welfare, Kansas City, Missouri, under the supervision of Mr. Herbert Clare from information obtained in the field, from consulting engineers' reports and from Corps of Engineers Flood Emergency Plan.

2. Distribution by Classification

Figure 3 on page12 is a map of the same area which classifies the sources detected by IR as possible or definite and also as to which flight resulted in detection. It is interesting to note that under nighttime conditions, 10 individual definite sources were detected as a result of the Monday a. m. flight (letter M only) that were not in evidence during the following flights. Also worthy of note is the fact that 6 definite sources detected under nighttime conditions on Tuesday were not seen previously.

3. Distribution by Identification

Figure 4 on page13 is a map of the same area, identical to Figure 3 except that the sources are identified. In order to indicate relative location more clearly, the sources have been numbered. The code letters are identical to those in Figure 2 and may be cross-referenced. This map was prepared as a result of a ground examination of the area after a preliminary study of the results obtained during the data-gathering flights.

What is probably the most significant point of the entire study is evidenced by this map; the fact that of the 26 sources classified as possible (letter P on Figure 3, page12), 23 are identified as actual sources.

E. SOURCES DETECTED

All of the 60 sources detected have been identified, 57 as actual sources. Two points listed as possible sources were blank; that is, there was no source in the area. The other is a creek that flows into the Missouri River in the Riverside district. The actual sources detected and identified are listed in this paragraph. Five of these are located in the Blue River and cannot be positively identified. The probable owner of the outfall is given. Of the remaining 52 sources, 34 are equal to or greater than 24" in diameter and 6 are 12" or less (one is a 10" diameter source--AM27).

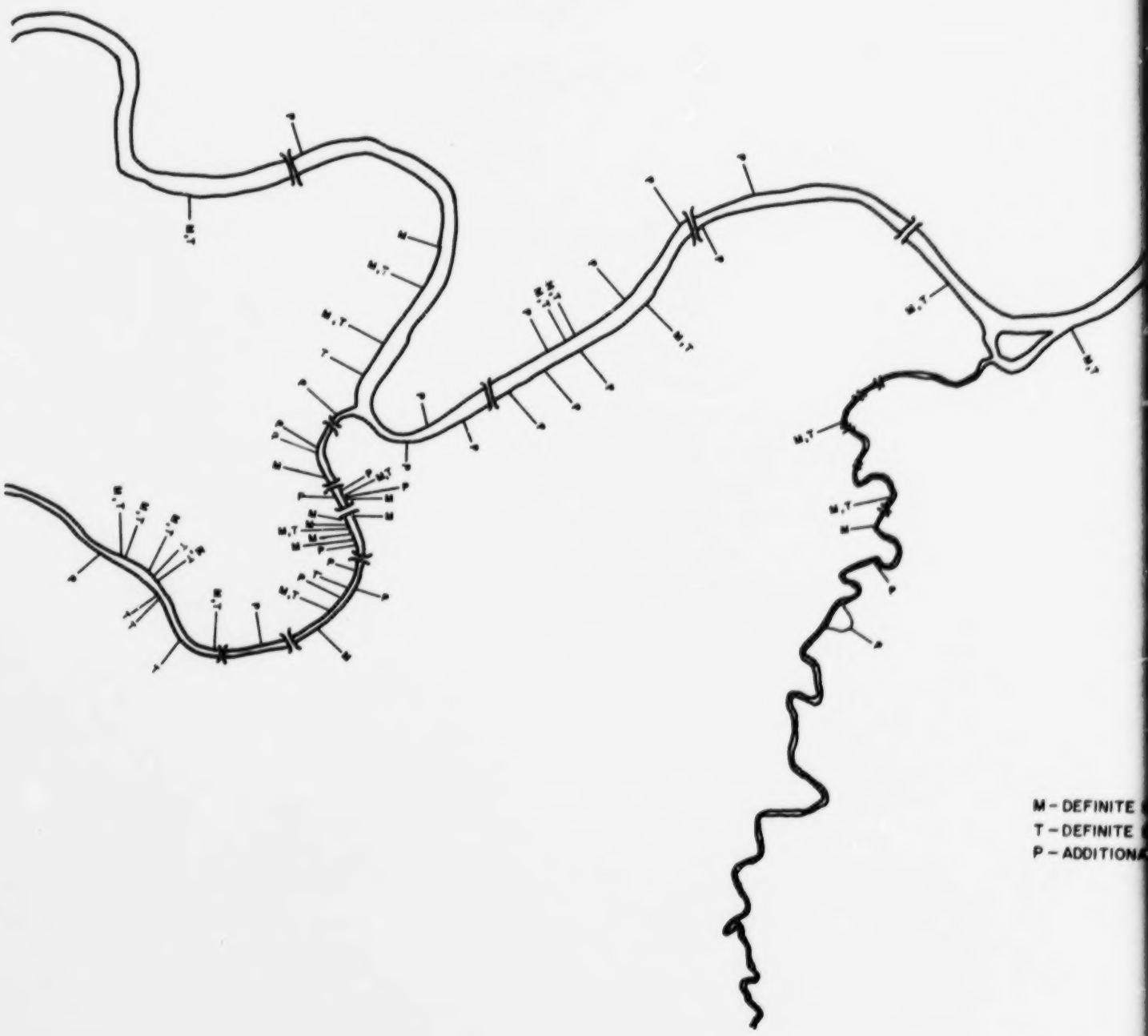
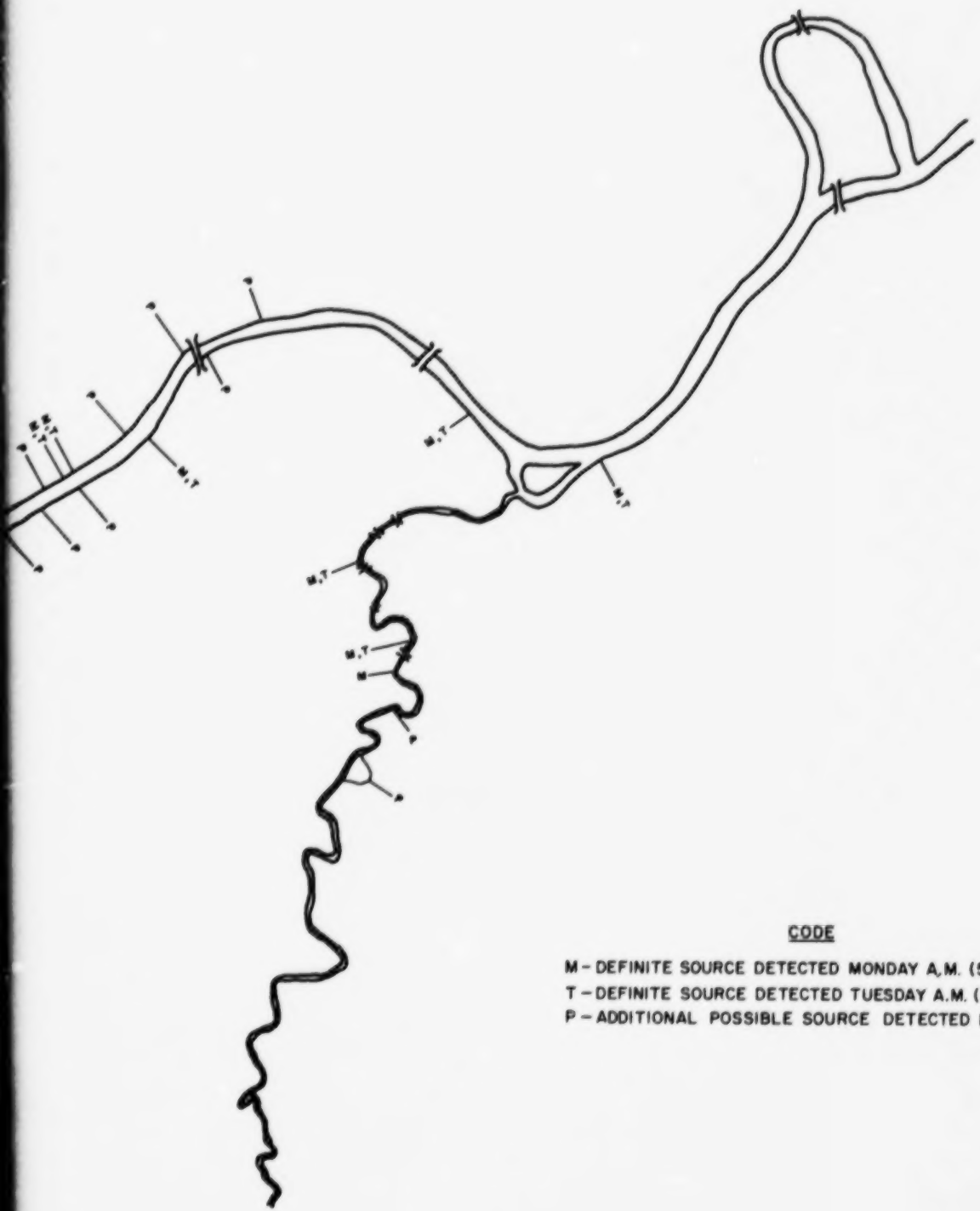


Figure 3. Source Classification

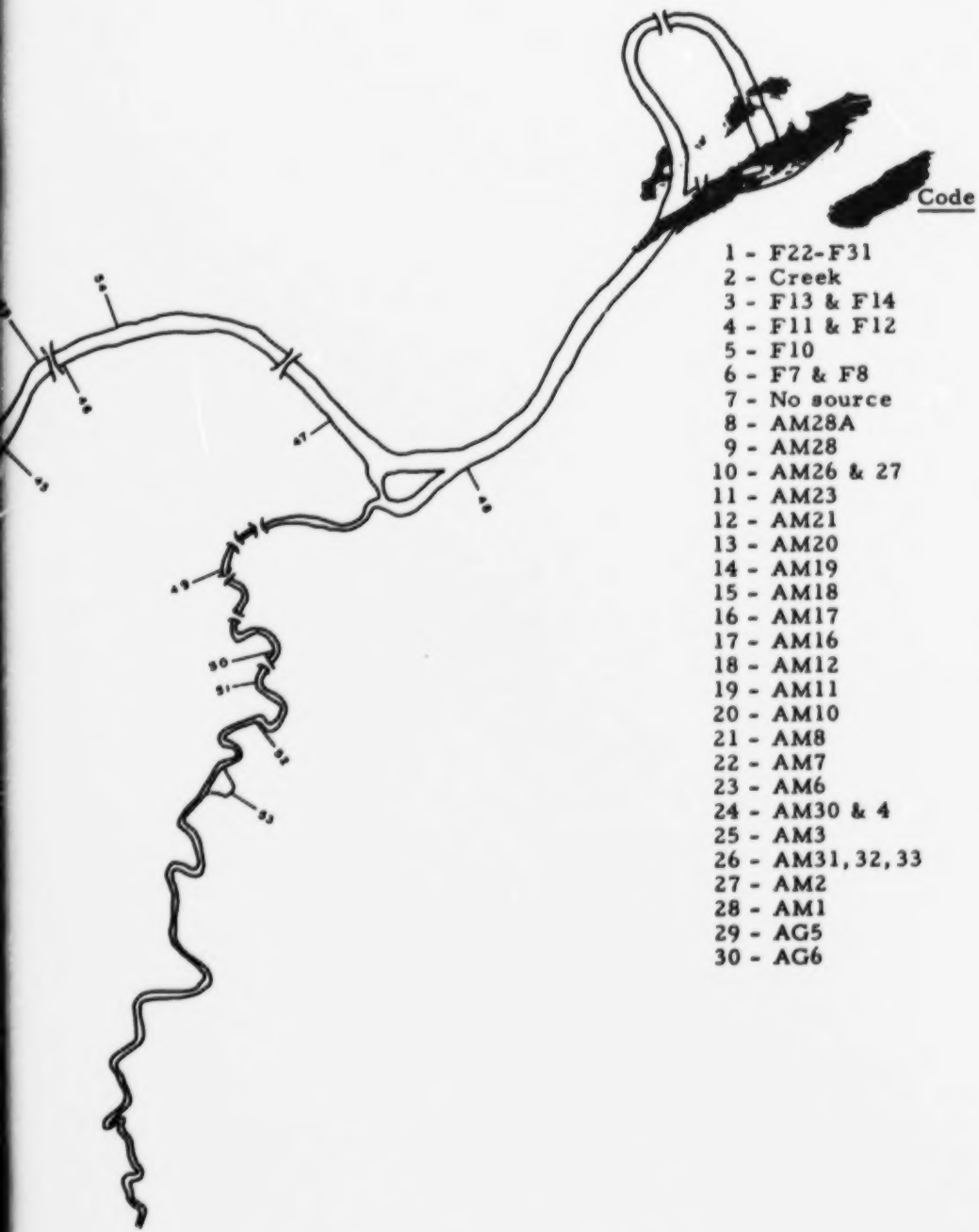


CODE

M – DEFINITE SOURCE DETECTED MONDAY A.M. (5 JUNE 1961)
T – DEFINITE SOURCE DETECTED TUESDAY A.M. (6 JUNE 1961)
P – ADDITIONAL POSSIBLE SOURCE DETECTED DURING DAYLIGHT FLIGHT

Figure 3. Source Classification

Figure 4. Source Identification



Code

1 - F22-F31
2 - Creek
3 - F13 & F14
4 - F11 & F12
5 - F10
6 - F7 & F8
7 - No source
8 - AM28A
9 - AM28
10 - AM26 & 27
11 - AM23
12 - AM21
13 - AM20
14 - AM19
15 - AM18
16 - AM17
17 - AM16
18 - AM12
19 - AM11
20 - AM10
21 - AM8
22 - AM7
23 - AM6
24 - AM30 & 4
25 - AM3
26 - AM31, 32, 33
27 - AM2
28 - AM1
29 - AG5
30 - AG6
31 - AG7
32 - AG10 & 10A
33 - C25
34 - C21
35 - C15
36 - C14
37 - C13
38 - C12
39 - C11
40 - C5
41 - C3
42 - E1
43 - E2
44 - E3
45 - E6
46 - E8
47 - E9A
48 - Sugar Creek Sewer
49 - Wilson Ave. Sewer
50 - 12th Ave. Sewer
51 - Rubberoid Co.
52 - Union Wire Rope Plant
53 - Unknown
54 - N9A
55 - N9
56 - No Source
57 - N7
58 - N6
59 - N5
60 - N4

Figure 4. Source Identification

NUMBER	SOURCE
1. F22-31	1. Water and Light Plant outlet.
2. Creek	2. Creek
3. F13 + 14	3. Fairfax Airport System and P. P. F-7.
4. F11 + 12	4. Phillips Petroleum Co. and P. P. F-8.
5. F10	5. Phillips Petroleum Co.
6. F7 + 8	6. Jersey Creek
7. No Source	7. No Source
8. AM28A	8. Not Listed
9. AM28	9. Splitlog outfall sewer
10. AM26 + 27	10. Central Ave. P. P. outfall
11. AM23	11. B. + G. Wrecking and Supply sewer outfall
12. AM21	12. K. C. Stockyard sewer outfall
13. AM20	13. K. C. Stockyard sewer outfall
14. AM19	14. Swift and Co. sewer outfall
15. AM18	15. Swift and Co. sewer outfall
16. AM17	16. K. C. Stockyards outfall
17. AM16	17. K. C. Stockyards outfall
18. AM12	18. Glazer Kaufman outfall
19. AM11	19. Shawnee Ave. P. P. outfall
20. AM10	20. KAW Warehouse and storage drain
21. AM8	21. Midwest Cold Storage sewer
22. AM7	22. Mill St. P. P. outfall
23. AM6	23. 12th St. Sewer P. P. outfall
24. AM30 & 4	24. Kansas City, Kansas Municipal Pwr. Plt. Rtn.
25. AM3	25. Osage Ave. P. P. outfall

26. AM31, 32, 33	26. K. C., Kansas Municipal Pwr. Plt. Intk.
27. AM2	27. Procter and Gamble waste outfall
28. AM1	28. Procter and Gamble waste outfall
29. AG 5	29. A. T. and S. F. Railroad
30. AG6	30. Sinclair Refining Co.
31. AG7	31. Kaw Valley Drainage District
32. AG10 & 10A	32. 16th St. sewer outfall and Ruby Ave. storm sewer
33. C25	33. Turkey Creek Div. Tunnel outlet
34. C21	34. Turkey Creek - O. K. Creek sewer outfall
35. C15	35. K. C. Stockyard Co.
36. C14	36. Stockyards #3 P. P. outfall
37. C13	37. K. C. Stockyards Co.
38. C12	38. K. C. Stockyards Co.
39. C11	39. K. C. Stockyards Co.
40. C5	40. Santa Fe Street P. P. outfall
41. C3	41. Broadway Bridge outfall
42. E1	42. Holmes St. sewer outfall
43. E2	43. Gillis St. sewer outfall
44. E3	44. Lydia Ave. sewer outfall
45. E6	45. Prospect Ave. sewer outfall
46. E8	46. Milwaukee Bridge sewer outfall
47. E9A	47. Not Listed
48. No Ref.	48. Sugar Creek sewer
49. No Ref.	49. Wilson Ave. sewer
50. No Ref.	50. 12th Ave. sewer

51. No Ref.	51. Rubberoid Co.
52. No Ref.	52. Union Wire Rope Plant
53. No Ref.	53. Unknown
54. N9A	54. Buckeye Creek sewer outfall
55. N9	55. Rock Creek P. P. outfall
56. No Source	56. No Source
57. N7	57. Howell St. P. P. outfall
58. N6	58. Corn Products Refining Co. P. P. outfall
59. N5	59. Burlington Ave. P. P outfall
60. N4	60. Municipal Airport P. P. #1 outfall

F. SOURCES NOT DETECTED

In this section are listed all sources which were not detected. Also given is the probable reason for failure to detect. These causes were determined during the ground examination of the area mentioned in the previous paragraph. Although all sources were not examined, a sufficient number were observed that included at least one example of the various types listed.

Note that of the 73 sources listed, 12 are pumping plants of intermittent operation, 11 are purely storm water drains, 3 are buried, and 1 is no longer in use. Of the remaining 46 sources, 29 are pipes of either cast iron, steel or corrugated metal. The largest of these is 42" in diameter and only 6 are greater than 24" in diameter. The diameter in 11 cases is 1 foot or less. The predominant small size explains in part the failure to detect these sources.

The size of the source is, however, not necessarily the limiting factor. A small outlet which possesses a flow of considerable volume will result in detection. This is demonstrated by the fact that 12 sources were detected whose diameter is less than 24".

The following Table summarizes the various sources not detected, and presents probable reasons for failure to detect

Source	Total	Probable Cause of Failure to Detect
F32, F33, F19, F20, F21, F18, F17, F16, F15, F4, F3, F2, F3a, AM28A, B, C, D, E, F, G, AM25, AG11, E4, N3	24	Insufficient outflow or storm drain
AM15, AM14, AM13, F9, F6, C10 thru C7, C4, C1, C24, C23, C22, N8	16	Small diameter drains.
F5, 5A, 5B, AM22, AM9, AM5		Not in use at time of observation
AM24, AM29, E7, E9	10	Buried
E5	1	No longer in use
N2	1	Intermittent operation
AG8, AG9, E1A, E1B, N1	5	Unknown.
AG11 thru AG21, C16 thru 20.	16	Obscured by brush

Table 1. Summary of Sources Not Detected

G. COMPARATIVE PRINTS

1. Flight Variable

On pages 21 and 22 of the classified report are shown 4 comparative strips of the same area, Figures 5 through 8, one strip for each successful flight made. As can be seen from this comparison, the flights during hours of darkness provided a definite difference in gray scale between the river and pollution source. Note that during daylight hours (Figures 5 and 7) contrast between the sources and the river are much more subdued than during the hours of darkness (Figures 6 and 8). Also note that the river appears much warmer at night than during daylight.

2. Detector Variable (Nighttime)

On page 23 (Figures 9 and 10) is seen a comparison between detectors under nighttime operation, all other parameters being constant. Note that detail is much sharper using the type gold-doped germanium (AuGe) detector. This effect may be attributed to the necessity of operating the indium antimonide at a much lower sensitivity due to the higher gain amplifier used with this type detector. (NOTE: Since this time, operation with indium antimonide (InSb) has been greatly improved, giving comparable sensitivity and improved resolution.) Page 24 (Figures 11 and 12) features the Kansas City, Kansas Municipal Water and Light Plant, also under nighttime conditions.

3. Detector Variable (Daytime)

Pages 25 (Figures 13 and 14) and 26 (Figure 15) again compare a similar area with the detector variable during daylight hours. Notable in this selection is the fact that the outfall at the Sinclair Refining Company (AG6 and 7) is exceptionally evident only during that pass with a filtered AuGe detector.

4. Sources Evident Only on Monday (5 June 1961, 0100 hrs.)

An interesting fact evident as a result of the study is that under nighttime conditions, 10 individual sources were detected on Monday that were not evident during the other flights. These sources were identified as F13, AM27, AM21, AM20, AM19, AM18, C25, C15, and C14. The tenth source is located in the Blue River.

On this date, outfalls from the sources produced a gray scale more obvious than at any other time. Page 27 shows in particular C15 (circle a), AM21 (circle b), AM19 (circle c), AM18 (circle d) and AM16 (circle e), all located on Figure 16. The other strip (Figure 17) is included to illustrate the Osage Ave. P.P. Outfall (AM-3). Note that no gray scale difference exists between it and the river.

5. Sources Evident Only on Tuesday (6 June 1961, 0100 hrs.)

Six sources were detected Tuesday that were not evident previously. As in the previous paragraph, outfalls from these sources produced a gray scale more obvious on this date. These sources were AG6, AG7, AG10, and 10A, AM3, AM11 (Figure 19 circle), and F7 and 8. On page 28 (Figure 18), note that AM3 appears much hotter (whiter) than the same source on page 27 (Figure 17).

6. Blue River Sources

Note that there are few sources detected in the Blue River as seen on page 29 (Figures 20 and 21). Of special note is what appears to be a cold outfall at the extreme right of Figure 20. On the extreme left of the print can be seen what appears to be a hot outfall. No sources are evident in the Blue River section of the other print.

7. Sources Generally Evident Throughout Mission

Several sources that were detected during all flights are pictured on page 30 (Figures 22 and 23). The four most obvious outfalls are: F11 (Figure 22- circle a) - an open ditch from the Phillips Petroleum Co.; F10 (Figure 22 - circle b) - another outfall from Phillips (note effluence); N6 (Figure 23 - circle a) -Corn Products Refining Co.; and E6 (Figure 24, circle b) - Prospect Avenue Sewer outfall.

8. Possible Sources

An example of how reflectivity in daylight affects gray scale is seen on page 31 (Figures 24 and 25). Note that there is no gray scale difference between outfalls and the river. This type result was used to determine additional possible sources in that geometric discrepancies in the normal course of the riverbank are readily visible. Figure 25 (which includes the same area of the Kansas River as Figure 24) illustrates the necessity of placing an upper limit on aircraft altitude because of the loss of resolution with increased altitude. Note that individual sources (especially the smaller ones) are almost undiscernible whereas in Figure 24 they are quite evident.

9. Weather Conditions

Table 2 presents a summary of weather conditions and also river water temperatures at various testing stations. As is seen in the Table, river water temperatures were quite warm. Flights performed when water temperatures are at winter levels would very likely result in positive detection of many of the sources termed "possible" in this report.

Date	General Weather Conditions	Cloud Cover	Air Temp. °F.	Time	Water Temp., °F. Station 1	Missouri R Station 2	Station 3	Kansas R. Station 4	Blue R. (None)
4 June	Cloudy, hazy above no clouds below 1000' no rain 1300 hr.	Clouds high 1300 hr.	76 1300 hr.	0700 1300 1500	- 83 -	- 72 -	- 72 -	80 - 81	- - -
5 June	Partly cloudy no rain 0100 hr.	High thin clouds 0100 hr.	70 0100 hr.	0100 0700 1300 1500 2300	82 - 74 - -	72 - 73 - -	72 - 72 - -	- 81 - 81 81	- - - - -
	Partly cloudy 1/2 or less with clouds Bright conditions - sunny no rain - 1300 hr.	High clouds 1300 hr.	81 1300 hr.						
6 June	Partly cloudy occasional lightning west of weather station 0100 hr.	High clouds 0100 hr.	73 0100 hr.	0100 0700 2300	75 - -	74 - -	74 - -	- 75 82	- - -

Stations

1. Missouri River below confluence of Blue River at Standard Oil Co.
2. Kansas City, Kansas Power & Light Co. - Quindaro Station (Kansas City, Kansas Waterworks).
3. Kansas City, Missouri Water Works.
4. Kansas City, Kansas Power & Light Co. - Kaw Station.

Table 2. Weather and River Conditions During Test Flights

HRB

V. DEGREE OF SUCCESS

Of the 73 sources not detected (Section IV-F), it would seem reasonable to disregard those outfalls listed as storm and waste water drains, those buried and the one no longer in use. This gives us an adjusted total of 58 which when added to those sources identified on Figure 4, page 13 (total 51), results in an over-all total of 109 sources in the area. This figure does not include the Blue River and treats those outfalls of the Kansas City, Kansas Municipal Water and Light Plant as groups of sources rather than as individuals. (See Section IV-E, #1.)

In general, we may conclude that 51 sources were detected as a result of (1) temperature differential and (2) geometric variations. This means that the sources detected were obvious either because of gray scale difference or because of a geometric configuration on the film indicating an outfall. Four reasons may be extended accounting for the majority of cases in which the source was not detected:

(1) Intermittent operation,

(2) Insufficient outflow,

(3) IR view impeded by brush, etc.,

(4) Point of discharge below water level, with discharge colder than river water, so that it flows to river bottom where detection is impossible.

VI. CONCLUSIONS

As a result of the data collection flights, an analysis of the results and subsequent ground examination of the area, the following conclusions may be made.

1. Infrared detecting systems such as the one used on this exercise have a very useful place in pollution control surveys.
2. All sources of pollution cannot be detected. This is especially true of sources which contribute a very small volume, even though such sources may contribute a high concentration.
3. Relative temperature of water and outfall is the major factor in detecting definite sources.
4. The effect of reflectivity renders those results of flights conducted in daylight hours useless for determining definite sources as such. However, additional possible outfalls are more obvious under these conditions and in the great majority of cases are in reality actual sources.
5. Size and nature of the body under survey are the limiting factors in determining aircraft altitude and, to a lesser extent, aircraft speed.
6. Very few sources were detected in the Blue River due to the heavy vegetation present. For this type of terrain data should be collected when trees do not have foliage.
7. A ground inspection of the area after a preliminary study of the film results was instrumental in identifying individual sources. Corps of Engineer Emergency Flood Plan charts were also an outstanding aid.
8. Flights should have been conducted at other times of night since maximum flow for all sources does not necessarily occur at the same time.

VII. RECOMMENDATIONS

The results obtained on these preliminary investigations indicate that further similar investigations would yield information very useful to pollution studies. However, any further data collection flights should be executed at a time when all possible variables could be utilized in such a way that maximum data would be obtained. For instance:

1. Pollution studies should be conducted in the very late fall before ice forms or in the very early spring after the ice has disappeared. At these times, temperature differentials between contributing sources of pollution and main river bodies will be at maximums.

2. Survey flight hours should be set up to include those hours a short time after sundown, since it is reasonable to assume that the outflows from many industrial sources diminish at the close of the working day, whereas the flow of domestic wastes would tend to increase.

3. Ground observation of the area under study should be performed after initial study of the results in order to determine the characteristics and origin of each source.

4. Further study should be pursued on types of outfalls that can be detected consistently.

5. Daytime flights using an optical filter for removing reflected solar radiation should be conducted to record outfalls from industries that discharge only in daylight hours.